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Description of Steam Condensation Phenomena During the Loss-of-Coolant Accident

E. W. McCauley and G. S. Holman
Lawrence Livermore National Laboratory
Livermore, California U.S.A.

E. Aust, H. Schwan, J. Vollbrandt, and H. Fürst
GKSS Forschungszentrum Geeshacht GmbH
Geesthacht-Tesperhude, West Germany

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E. W. McCauley and G. S. Holman

University of California
Lawrence Livermore National Laboratory
P. O. Box 808, L-140
Livermore, California 94550

E. Aust
H. Schwan
J. Vollbrandt

GKSS Forschungszentrum Geesthacht GmbH
Federal Republic of Germany

SUMMARY

The development and verification of advanced computer models which describe the boiling water reactor (BWR) pressure suppression process for a hypothetical loss-of-coolant accident (LOCA) requires a clear description of basic steam condensation phenomena. These complex transient phenomena give rise to significant impulsive loading in the wetwell difficult to quantify but important to safe design.

The GKSS Research Center, in coordination with interested institutions of West Germany and the United States, is currently conducting a test program for such basic research on a multivent BWR-related pressure suppression system. The Lawrence Livermore National Laboratory (LLNL) acts as the principal U.S. NRC liaison for this test program, with particular emphasis on development of GKSS data for confirmatory use regarding U.S. Mark II nuclear power plants as well

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as to advanced code development. The multivent test facility, placed in operation in February 1979, is a three-pipe full-scale vent system modelling main features of both the West German KWU and United States G.E. Mk II BWR pressure suppression systems. The time-correlated measurements system consists of approximately 190 test data transducers, three television cameras which view both the water surface and vent pipe outlets, and a high speed (1000 fps) 16mm camera which observes a single vent pipe outlet. This unique combination of visual data with vent pipe and wetwell pool pressure and temperature data allows the identification and description of specific chugging phenomena.

The GKSS-PSS tests to date have investigated effects due to steam-break flow rate and initial wetwell temperature. All tests have consistently yielded a close coupling of events throughout the drywell, wetwell, and vent pipes as well as a strong correlation between physical and high-speed visual data obtained from the tests. In particular, significant progress has been made toward understanding the late-time chugging events; because of their dynamic character they are of considerable importance to safety assessments. The lean suppression (chugging) events evidence a strong positive pressure peak followed by a high-frequency ringdown characteristic of the natural frequency of the submerged wetwell system. The chug source appears to be facility-independent and can be identified with a strong rarefaction that is correlated to the formation and rapid collapse of a steam ring which forms in the vent exit at the end of steam flow. We have observed that the collapse of this steam ring, which appears to initiate the ringdown, occurs well after the time of maximum steam intrusion into the pool. This observation argues against the more traditional concept of a steam "bubble" at the vent exit. In fact, evidence collected from temperature transducers and high speed film suggests the steam plume which penetrates into the pool is partially hollow, bearing little resemblance to a true bubble. This phenomena remains consistent throughout tests with initial pool temperatures ranging from 25°C to 60°C, although the steam intrusion dynamics vary considerably with temperature.

We have also observed that the chugging process is only weakly dependent on initial drywell pressurization rate, implying that the phenomena are derived primarily from a condition of starved flow, rather than from any particular LOCA initialization condition.